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(54) **HEATED INFLATION SYSTEM**

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(52) **U.S. Cl.**
CPC . ***C06D 5/00*** (2013.01); ***B64D 25/14*** (2013.01)

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CPC Y10S 244/905; B64D 25/14; B64D 45/00; B64C 25/56; B60R 21/26; B60R 2021/2607
USPC 102/530; 244/905, 137.2; 280/741, 280/728.1
See application file for complete search history.

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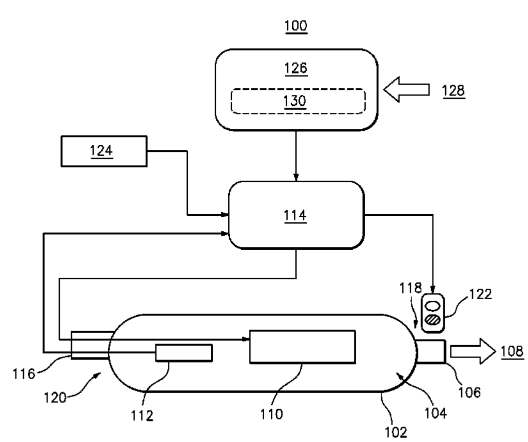
(57) **ABSTRACT**

A heated inflation system for an inflatable device on an aircraft is provided. The heated inflation system includes an inflation cylinder configured to hold a gas mixture under pressure, a heating element configured to selectively heat the gas mixture, and a temperature sensor configured to sense a temperature of the gas mixture. The heated inflation system also includes a control module coupled to the heating element and the temperature sensor. The control module is configured to regulate heat applied by the heating element to the gas mixture based on a sensed temperature from the temperature sensor.

13 Claims, 3 Drawing Sheets



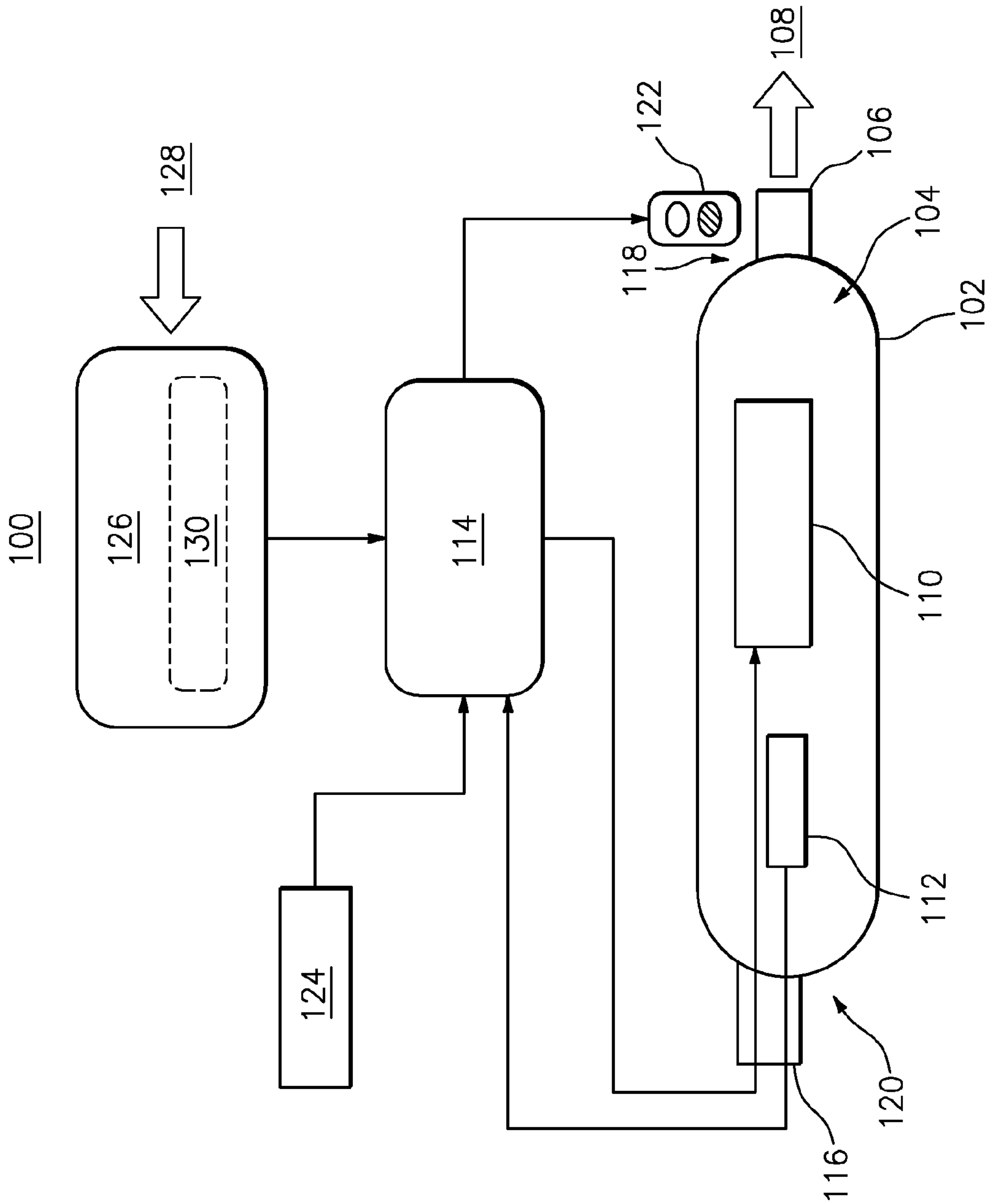


FIG. 1

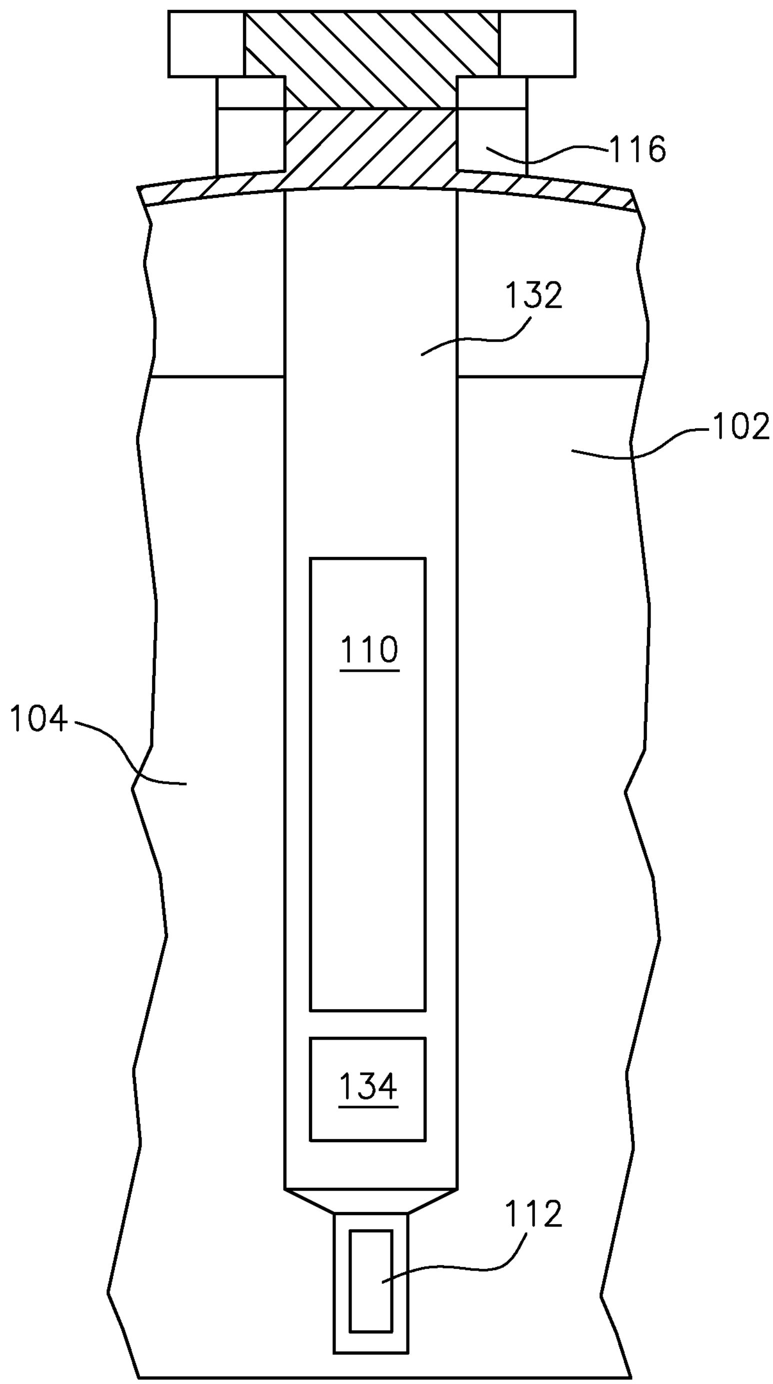


FIG. 2

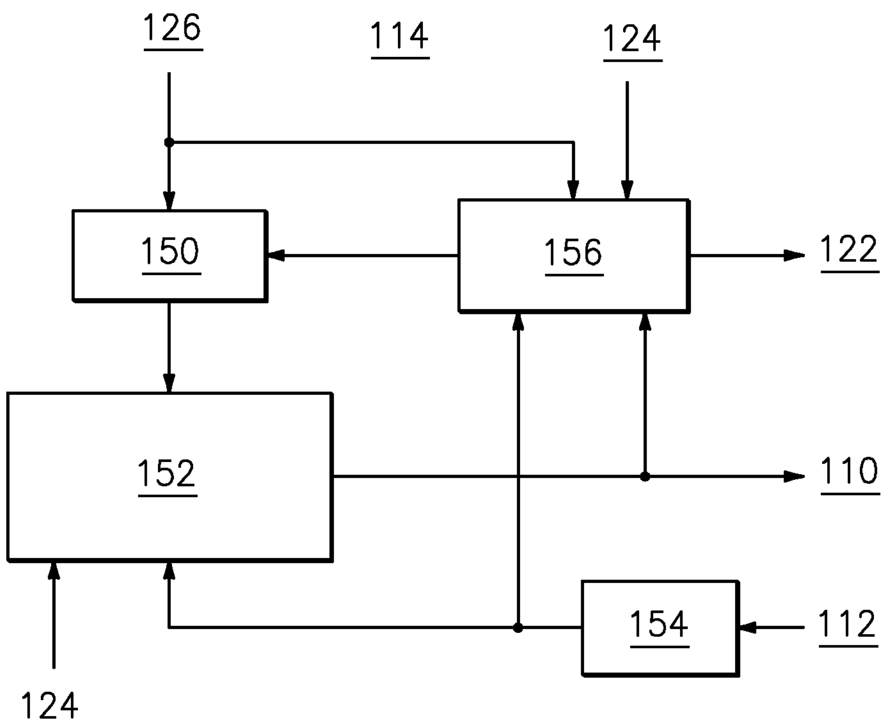


FIG. 3

HEATED INFLATION SYSTEM

BACKGROUND OF THE INVENTION

The subject matter disclosed herein relates to inflatable evacuation systems. More specifically, the subject disclosure relates to a heated inflation system.

A conventional inflation system for an aircraft evacuation slide includes a compressed gas cylinder with a few mechanical parts to regulate and direct gas flow to a slide system. The compressed gas cylinder, also referred to as an inflation cylinder, is sized based on evacuation slide performance requirements at an extreme cold temperature, e.g., −65 degrees F. (−53.88 degrees C.). The compressed gas cylinder is typically sized to provide a portion of the volume needed to inflate the aircraft evacuation slide, with the remaining volume supplied by ambient air pulled into the aircraft evacuation slide through an aspirator. The size and weight of the compressed gas cylinder is a significant contributor to the overall weight, volume and pack density of a packed slide system.

BRIEF DESCRIPTION OF THE INVENTION

According to one aspect, a heated inflation system for an inflatable device on an aircraft is provided. The heated inflation system includes an inflation cylinder configured to hold a gas mixture under pressure, a heating element configured to selectively heat the gas mixture, and a temperature sensor configured to sense a temperature of the gas mixture. The heated inflation system also includes a control module coupled to the heating element and the temperature sensor. The control module is configured to regulate heat applied by the heating element to the gas mixture based on a sensed temperature from the temperature sensor.

According to another aspect, a method of controlling a heated inflation system for an inflatable device on an aircraft is provided. The method includes sensing, by a temperature sensor coupled to a control module of the heated inflation system, a temperature of a gas mixture in an inflation cylinder of the heated inflation system as a sensed temperature. The method also includes comparing, by the control module, the sensed temperature to a set point value. The control module turns on a heating element based on determining that the sensed temperature is below the set point value, where the heating element is configured to selectively heat the gas mixture. The control module turns off the heating element based on determining that the sensed temperature is above the set point value.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a heated inflation system according to an embodiment;

FIG. **2** is a view of a heating element assembly according to an embodiment; and

FIG. **3** is a block diagram of a control module of a heated inflation system according to an embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Exemplary embodiments provide a heated inflation system for an inflatable device, such as a slide, raft, or slide/raft combination for use on an aircraft. As an aircraft can operate in a wide range of temperature environments, inflatable evacuation systems must also be operable over a wide range of temperatures. In an inflatable evacuation system that relies upon an inflation cylinder, pressure within the inflation cylinder may decrease at lower temperatures which can reduce the rate of inflation of the inflatable device. Heating gas within the inflation cylinder and maintaining temperature around a set point value that is close to a typical ambient temperature can reduce the overall volume of gas needed to be stored within the inflation cylinder to accommodate low temperature conditions (e.g., −65 degrees F. (−53.88 degrees C.)), and thus reduce size and weight associated with the inflation cylinder. Accordingly, embodiments provide a heated inflation system for an inflation cylinder in an aerospace environment.

FIG. **1** depicts an example block diagram of a heated inflation system **100** according to an embodiment. The heated inflation system **100** includes an inflation cylinder **102** configured to hold a gas mixture **104** that is under pressure. The gas mixture **104** can be a combination of carbon dioxide and nitrogen gas blended at a ratio specific to requirements associated with an intended installation environment of the heated inflation system **100**. Similarly, the inflation cylinder **102** is sized according to requirements associated with an intended installation environment of the heated inflation system **100**. The inflation cylinder **102** includes a regulator assembly **106** configurable to maintain a release pressure of the gas mixture **104** as it exits the inflation cylinder **102** to inflate an inflatable device **108**. Additional components (not depicted) can be disposed between the regulator assembly **106** and the inflatable device **108**, such as tubing, an aspirator, and other elements known in the art. The inflatable device **108** can be, for example, a slide, raft, or slide/raft combination. The heated inflation system **100** and the inflatable device **108** can be installed in a packed slide system of an aircraft (not depicted).

A heating element **110** and a temperature sensor **112** may be disposed within the inflation cylinder **102** to selectively heat the gas mixture **104** and sense a temperature of the gas mixture **104**. The heating element **110** can be implemented as one or more flexible heaters, such as polyimide heaters, silicone rubber heaters, heating tape, or mica heaters. Alternatively, the heating element **110** can be implemented as an insertion heater, an immersion heater, a cartridge heater, or other heater type known in the art. A control module **114** is configured to regulate heat applied by the heating element **110** to the gas mixture **104** based on a sensed temperature from the temperature sensor **112**.

The heating element **110** and temperature sensor **112** can be coupled to the control module **114** through a port **116** in the inflation cylinder **102**. In the example of FIG. **1**, the port **116** is separately located from the regulator assembly **106**. The regulator assembly **106** may be located at a first end **118** of the inflation cylinder **102**, while the port **116** is located at a second end **120** of the inflation cylinder **102** opposite the first end **118**. Wiring the heating element **110** and temperature sensor **112** through the port **116** rather than through the regulator assembly **106** may enable use of an existing regulator assembly **106** without redesign to support internal heating of the inflation cylinder **102** and avoids obstruction of gas flow out the inflation cylinder **102**.

The control module **114** can also control a visual indicator **122** to provide a health status of the heated inflation system **100**. The visual indicator **122** may illuminate a green light when no fault is detected and a red light when a fault is detected. The visual indicator **122** may be located in close proximity to the inflation cylinder **102** or at a remote location, such as within an aircraft cockpit and/or a flight attendant panel (FAP).

The control module **114** may also be responsive to a reset input **124** which can reinitialize the control module **114**. The reset input **124** can be provided by a button, switch, or remote command from an aircraft bus (not depicted).

A power module **126** receives and conditions input power **128** to power the control module **114**. The input power **128** may be provided from an aircraft power bus or battery system (not depicted). The power module **126** can also include a battery backup **130** in case of loss of input power **128**.

FIG. **2** depicts a heating element assembly **132** within the inflation cylinder **102** of FIG. **1** according to an embodiment. The heating element assembly **132** is installed in the port **116** of the inflation cylinder **102**. The heating element assembly **132** may provide a metallic housing for the heating element **110** and the temperature sensor **112**. The heating element assembly **132** can be sized and positioned such that heat produced by the heating element **110** is substantially centrally concentrated within the inflation cylinder **102**. Insulation material **134** may be installed within the heating element assembly **132** between the heating element **110** and the temperature sensor **112** such that the temperature sensor **112** can more accurately sense the temperature of the gas mixture **104** rather than the temperature of the heating element **110**. The heating element assembly **132** is designed to withstand internal temperature and pressure variations of the inflation cylinder **102** while preventing leakage and reaction to the gas mixture **104**.

FIG. **3** is a block diagram of the control module **114** of the heated inflation system **100** of FIG. **1** according to an embodiment. The control module **114** can be implemented using a combination of hardware and software. Software may be embodied in a tangible non-transitory computer storage medium, such as non-volatile memory, that configures one or more processing circuits to execute a sequence of instructions. The control module **114** can include one or more application specific circuits, field programmable circuits, and/or programmable logic devices configured to perform the processes as described herein.

In the example of FIG. **3**, the control module **114** includes a power controller **150**, a heating element controller **152**, a temperature sensor interface **154**, and a health monitor **156**. The power controller **150** is configured to receive power from the power module **126** and provide power to the heating element controller **152**. The power controller **150** may also provide local lower voltage power rails to run electronics within the control module **114**. The power controller **150** may receive information from the power module **126** or be able to determine a source of the input power **128** and whether power is provided by the battery backup **130** of FIG. **1**. For example, there may be separate physical inputs that provide power from an aircraft bus, ground power, and/or battery power, and the power controller **150** can determine which input or inputs are active. Depending upon which power source is active, different monitoring thresholds can be applied to determine health of the heated inflation system **100** of FIG. **1**. Additionally, the heating element controller **152** may use a lower temperature set point value for activating the heating element **110** if operating in a reduced power mode, e.g., the battery backup **130** of FIG. **1** is active.

The temperature sensor interface **154** receives a sensed temperature from the temperature sensor **112** and provides the sensed temperature to the heating element controller **152** and the health monitor **156**. The temperature sensor interface **154** may apply an engineering unit conversion to the sensed temperature to convert, for example, analog-to-digital converter counts into a temperature value in degrees C. or degrees F. The heating element controller **152** compares the sensed temperature from the temperature sensor interface **154** and determines whether the temperature of the gas mixture **104** of FIG. **1** is above or below a set point value. If the sensed temperature is below the set point value, the heating element controller **152** commands the heating element **110** to turn on, allowing power from the power controller **150** to pass through to the heating element **110**. If the sensed temperature is above the set point value, the heating element controller **152** commands the heating element **110** to turn off, preventing power from the power controller **150** to pass through to the heating element **110**. There may be a threshold band of hysteresis values applied to the set point value to prevent on/off cycling. For instance if the set point is 77 degrees F. (25 degrees C.), a +/−10 degree band may be applied. The heating element controller **152** may also receive the reset input **124**, and in response thereto, reinitialize itself to a set of initial conditions, e.g., reload set point and hysteresis values and clear temporary variables.

The health monitor **156** may monitor a number of inputs to determine if a fault condition exists. For example, the health monitor **156** can monitor voltage and/or current from the power module **126**, an output of the heating element controller **152** to the heating element **110**, and the sensed temperature from the temperature sensor **112** as conditioned by the temperature sensor interface **154**. The health monitor **156** may also initiate built-in tests to check the health of monitored elements. When a fault condition is detected by the health monitor **156**, such as a power fault, a heating element fault, or a temperature sensor fault, the health monitor **156** can output a fault indication on the visual indicator **122**, e.g., activate a red light. A power fault may be a low power condition where insufficient power is available to drive the heating element **110**. A heating element fault may be a heating element **110** open or heating element **110** shorted condition including any part of the wiring/interface between the control module **114** and the heating element **110**. A temperature sensor fault may be a temperature sensor **112** open or temperature sensor **112** shorted condition including any part of the wiring/interface between the control module **114** and the temperature sensor **112**.

The health monitor **156** can also be configured to detect if the heating element **110** enters an uncontrolled heating mode, such as reaching a maximum safe operating temperature. As one example, the maximum safe operating temperature may be about 150 degrees F. (65.56 degrees C.). Upon reaching the maximum safe operating temperature, the health monitor **156** may command the power controller **150** to disconnect power and thereby turn off the heating element **110**. Reaching the maximum safe operating temperature may also be indicated as a fault on the visual indicator **122**. Similar to the heating element controller **152**, the health monitor **156** may also receive the reset input **124**, and in response thereto, reinitialize itself to a set of initial conditions, e.g., reload monitoring parameters, clear temporary variables, and initiate built-in tests. When the control module **114** is operational and all built-in tests have successfully completed, the health monitor **156** may output a green light on the visual indicator **122** to indicate a system ready/operable condition.

Although only individual instances of the power controller **150**, heating element controller **152**, temperature sensor interface **154**, and health monitor **156** are depicted in FIG. **3**, it will be understood that multiple instances of one or more of the power controller **150**, heating element controller **152**, temperature sensor interface **154**, and health monitor **156** can be implemented for redundancy, such as a duplex or triplex system. Additionally, the power controller **150**, heating element controller **152**, temperature sensor interface **154**, and health monitor **156** can be combined or further subdivided within the scope of various embodiments.

A method of using the control module **114** to control the heated inflation system **100** of FIG. **1** includes sensing, by the temperature sensor **112** coupled to the control module **114** of the heated inflation system **100**, a temperature of the gas mixture **104** in the inflation cylinder **102** of the heated inflation system **100** as a sensed temperature. The control module **114** compares the sensed temperature to a set point value and may apply a hysteresis band to the set point value when comparing the sensed temperature to the set point value. The control module **114** turns on the heating element **110** based on determining that the sensed temperature is below the set point value, and the control module **114** turns off the heating element **110** based on determining that the sensed temperature is above the set point value. The control module **114** can receive power from the power module **126** and determine whether the power is provided by the battery backup **130**. The power controller **150** of the control module **114** can provide power to the heating element controller **152** of the control module **114** for the heating element **110**. The temperature sensor interface **154** can provide the sensed temperature from the temperature sensor **112** to the heating element controller **152**. The health monitor **156** of the control module **114** can determine whether a fault indication is detected. The health monitor **156** controls the visual indicator **122** based on the fault indication. The health monitor **156** may control the visual indicator **122** based on one or more of: a power fault, a heating element fault, over pressurizing and a temperature sensor fault.

While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

The invention claimed is:

1. A heated inflation system for an inflatable device on an aircraft, comprising:

an inflation cylinder that holds a gas mixture under pressure;

a heating element that selectively heats the gas mixture;

a temperature sensor configured to that senses a temperature of the gas mixture, wherein the heating element and the temperature sensor are internally disposed within the inflation cylinder; and

a control module coupled to the heating element and the temperature sensor, the control module regulates heat applied by the heating element to the gas mixture based on a sensed temperature from the temperature sensor, wherein the heating element and the temperature sensor are coupled to the control module through a port of the inflation cylinder, and the inflation cylinder further comprises a regulator assembly at a first end of the inflation cylinder and the port is located at a second end of the inflation cylinder.

2. The heated inflation system of claim **1**, wherein the heating element and the temperature sensor are internally disposed within a heating element assembly installed in the port.

3. A heated inflation system for an inflatable device on an aircraft, comprising:

an inflation cylinder that holds a gas mixture under pressure;

a heating element that selectively heats the gas mixture;

a temperature sensor that senses a temperature of the gas mixture, wherein the heating element and the temperature sensor are internally disposed within a heating element assembly installed in a port of the inflation cylinder, and insulation material is installed within the heating element assembly between the heating element and the temperature sensor; and

a control module coupled to the heating element and the temperature sensor, wherein the control module regulates heat applied by the heating element to the gas mixture based on a sensed temperature from the temperature sensor, and the heating element and the temperature sensor are coupled to the control module through the port of the inflation cylinder.

4. The heated inflation system of claim **1**, further comprising a visual indicator coupled to the control module, wherein the control module determines a fault indication of the heated inflation system and controls the visual indicator based on the fault indication.

5. The heated inflation system of claim **1**, further comprising a power module that provides power to the control module from one of: input power and a battery backup.

6. The heated inflation system of claim **1**, wherein the control module further comprises a heating element controller that turns the heating element on and off based on comparison of the sensed temperature to a set point value including a hysteresis band.

7. The heated inflation system of claim **6**, wherein the control module further comprises a power controller that provides power to the heating element controller for the heating element, a temperature sensor interface that receives the sensed temperature from the temperature sensor and provides the sensed temperature to the heating element controller, and a health monitor that controls a visual indicator based on one or more of: a power fault, a heating element fault, and a temperature sensor fault.

8. A method of controlling a heated inflation system for an inflatable device on an aircraft, comprising:

sensing, by a temperature sensor coupled to a control module of the heated inflation system, a temperature of a gas mixture in an inflation cylinder of the heated inflation system as a sensed temperature;

comparing, by the control module, the sensed temperature to a set point value;

turning on, by the control module, a heating element based on determining that the sensed temperature is below the set point value, wherein the heating element selectively heats the gas mixture;

turning off, by the control module, the heating element based on determining that the sensed temperature is above the set point value;

determining, by the control module, whether a fault indication is detected; and

controlling a visual indicator by the control module based on the fault indication;

wherein the heating element and the temperature sensor are internally disposed within the inflation cylinder and are coupled to the control module through a port of the inflation cylinder and wherein the inflation cylinder further comprises a regulator assembly at a first end of the inflation cylinder and the port is located at a second end of the inflation cylinder.

9. The method of claim **8**, wherein the heating element and the temperature sensor are internally disposed within a heating element assembly installed in the port.

10. The method of claim **9**, wherein insulation material is installed within the heating element assembly between the heating element and the temperature sensor.

11. The method of claim **8**, further comprising:

receiving power at the control module from a power module; and

determining, by the control module, whether the power is provided by a battery backup.

12. The method of claim **8**, further comprising applying a hysteresis band to the set point value when comparing the sensed temperature to the set point value.

13. The method of claim **8**, further comprising:

providing power to a heating element controller of the control module for the heating element;

providing the sensed temperature to the heating element controller; and

controlling the visual indicator by a health monitor of the control module based on one or more of: a power fault, a heating element fault, and a temperature sensor fault.

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